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ABSTRACT

The purpose of this interpretive case study is to make sense of the way a female high school student interacts with a male physics teacher. This paper highlights the actions and interactions of the female student according to her own way of knowing which is consistent with how many female adolescents make sense of their experience. Two story narratives are used to describe the student's sense making in the context of her experienced and preferred classroom environments. The differences between what she experiences and what she prefers make explicit the incompatible world views which constrain her participation in the physics class. Significant findings are: (1) the female learner has a desire to enter into a caring relationship with the teacher to learn the physics content; (2) the teacher's form of humor constrains the student's connectedness with him; (3) the student comes to a better understanding of physics concepts through discussions in which her voice is valued; and (4) multiple instructional strategies enable the student to enter into an array of caring relationships which motivate her to participate in learning activities. Contains 35 references. (Author/JRH)

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STORIES OF A FEMALE LEARNER IN A HIGH SCHOOL PHYSICS CLASSROOM: CARE, CONNECTEDNESS, AND VOICE

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Abstract

The purpose of the interpretive case study is to make sense of the way a female high school student interacts with a male physics teacher. The research is part of a dissertation designed to investigate student understanding of mechanics in the context of gender and ethics. This paper contributes to the "growing body of research [that] documents the need to change the way science is taught in order to appeal to women" (Rosser, 1995, p. 3). Gender is defined as: (1) the masculine way of knowing, which is how the traditional patterns of Western science have evolved, emphasizing objective, rational, logical, and linear thinking (Shepherd, p. 21); and (2) the feminine way of knowing emphasizing more intimate forms of caring and connectedness with others and ideas (Gilligan, 1982; Noddings, 1992; Belenky, Clinchy, Goldberger, & Tarule, 1986). This paper highlights the actions and interactions of a female student according to her own way of knowing which is consistent with how many female adolescents make sense of their experiences. Two story narratives describe the student's sense making in the context of her experienced and preferred classroom environments. The differences between what she experiences and what she prefers make explicit the incompatible worldviews which constrain her participation in the physics class. In her experienced classroom, the teacher's form of classroom humor silences her voice. The student perceives a lack of caring and connectedness with the teacher due to his form of humor that she attributes to the way that male teachers talk. The student prefers a physics classroom where her voice is valued so she may develop rapport with the teacher to learn the physics content. She refers to this kind of communication as consistent with the way that female teachers talk to students. Significant findings are: (1) the female learner has a desire to enter into a caring relationship with the teacher to learn the physics content; (2) the teacher's form of humor constrain the student's connectedness with him; (3) the student comes to a better understanding of physics concepts through discussions in which her voice is valued; and (4) multiple instructional strategies enable the student to enter into an array of caring relationships which motivate her to participate in learning activities.

Purpose

The purpose of the case study is to interpret a female high school student's interactions with a male physics teacher. The research is part of a dissertation designed to investigate student understanding of mechanics and classroom ethics as well as gender. This paper contributes to the "growing body of research [that] documents the need to change the way science is taught in order to appeal to women" (Rosser, 1995, p. 3).

Gender is defined as: (1) the masculine way of knowing, which is consistent with the Western science ethos, emphasizing objective, rational, logical, and linear thinking (Shepherd, p. 21); and (2) the feminine way of knowing emphasizing more intimate forms of caring and connectedness (Gilligan, 1982; Noddings, 1992). The actions and the interactions of the female student are interpreted through the lens of gender. The following issues focus the research. Based on the student and teacher actions and interactions in the classroom: (1) compare and contrast the female student's experienced and preferred classroom environments; (2) link her understanding of physics with caring and connected ways of knowing; and (3) describe how her voice evolves.

Gender is a sense making referent that bifurcates into masculine and feminine ways of knowing. Masculine and feminine sense making does not imply that all males and females construct meanings in similar ways, but gender does significantly relate to: (1) how individuals construct their own identity; (2) how individuals interpret the actions of others; and (3) how individuals use language to share meaning, and these issues pertain to the teaching and learning of secondary science. In contrast to gender, sex is defined as the physiological traits of sexually reproducing beings. The significance of this paper is that the findings do not apply to the actions and interactions of one sex or the other. Rather, the findings, apply to some degree to all learners since feminine traits can be found to varying degrees in both males and females.

Science, Gender, & Culture

By the time children reach adolescence, they have internalized many socio-cultural norms from their experiences with parents and peers. Children construct gender in the context of socio-cultural norms that favor particular ways of knowing for males and for females. Keller writes, "it is . . . our mothers who provide the emotional context out of which we forge the discrimination between self and other, [that] inevitably leads to a skewing of our perceptions of gender" (1985, p. 85). Thus, gender is a product of the socio-cultural life experiences of the developing child.

A commitment of connectedness between teachers and students grows out of caring relationships (Noddings, 1984, 1988, 1993). According to Noddings (1988), it is desirable that teachers and students interact as the carer and the cared-for. Teachers who enter into caring relationships with their students promote rich conversations with female learners. Rich conversations occur as students and teachers engage in " a common search for understanding, empathy, or appreciation" (Noddings,

1992, p. 23) as they negotiate the meaning of science concepts. These traits are essential for the development of the voices of girls.

For female learners, voice is gained through caring and connectedness. The development of the feminine voice represents a caring and connected way of knowing. "For most women," states Tannen, "the language of conversation is primarily a language of rapport: a way of establishing connections and negotiating relationships" (1990, p. 77). The 'language of rapport' contributes to the development of voice. Voice is more than a point of view, it is a referent for the experience and the development of females (Belenky, Clinchy, Goldberger, & Tarule, 1986). Belenky et al. (1986) suggest that:

> Educators can help women develop their own authentic voices if they emphasize connection over separation, understanding and acceptance over assessment, and collaboration over debate; if they accord respect to and allow time for the knowledge that emerges from firsthand experience; if instead of imposing their own expectations and arbitrary requirements, they encourage students to evolve their own patterns of work based on the problems they are pursing. (p. 229)

Science and gender are politically driven historical constructs originating in the tradition of the Western European cultures that have evolved from the Enlightenment. Gender and science are ways of knowing that connect with socio-cultural traditions. Western science is rational, objective, impartial, and value-free, and it is premised on a systematic process of experimentation designed to discover truths. Science, as a rational interpretation of experience, is most closely aligned with masculine ways of knowing because men have been the primary contributors of science. Shepherd writes that, "[b]ecause the majority of minds responsible for constructing science were male, the institution reflects masculine consciousness" (1993, p. 22). "Not only are mind and nature assigned gender," adds Keller, "but in characterizing scientific and objective thought as masculine, the very activity by which the knower can acquire knowledge is also genderized" (1985, p. 79).

Science is often described as a critical inquiry into experience (NRC, 1996). Influenced by the works of Popper, Aicken notes that "all scientific theories are open to suspicion" (1991, p. 55). Another central tenet of science is the principle of falsification. According to the construction of Western science, scientific knowledge is objective, contested, and never exact (Aicken, 1991). The issues of falsification and contested ways of knowing are more closely aligned to the masculine ways of knowing.

Traditional science as practiced in the West separates the knower from what is known (Belenky et al., 1986). This disconnectedness acts to silence many female learners since many of them rely on caring relationships as the conduit through which knowledge is constructed in a community. Science as an objective, value free form of rational inquiry isolates the knower from what is known. This separation is a developmental masculine trait. Scientific inquiry is consistent with masculine ways of knowing. As a result of this construction of science, feminine ways of knowing have not widely contributed to the construction of science.

From an alternative perspective, science is not an impartial nor a value-free way of knowing (Harding, 1991). Those who engage in science create empirical evidence of a hypothetical world.

Science is political since some members of certain cultures benefit from it while others do not. Science is related to power and control since:

> Groups with conflicting social agendas have struggled to gain control of the social resources that the sciences--their 'information,' their technologies, and their prestige--can provide. For those who have suffered from what seem to be the consequences of the sciences, their technologies, and their forms of rationality, it appears absurd to regard science as the value-free, disinterested, impartial Archimedean *arbiter* of conflicting agendas, as conventional mythology holds. (Harding, 1991, p. 10)

Gender, like science, binds power and control to the actions and interactions of individuals. Gender relates to the personal and social characteristics of individuals and groups based on their genetic and cultural inheritance. Gender as alternative ways of knowing are both masculine and feminine, and these two subclasses are described in parallel but distinctly different ways. Femininity is traditionally defined as subjective, irrational, and grounded whereas masculinity is objective, rational, and abstract. Keller writes that, " '[f]eminization' has become synonymous with sentimentalization. A woman thinking scientifically or objectively is thinking 'like a man'; conversely, a man pursuing a nonrational, nonscientific argument is arguing 'like a woman' " (1985, 77).

Science, gender, and culture are interrelated concepts significant to an understanding of what sense students make of their experiences in science classrooms. The significance of these concepts is that female learners have been and continue to be underrepresented in the physical sciences because of the socio-cultural construction that aligns science with masculine ways of knowing. Many female learners in secondary physics classrooms must struggle against this cultural perception since they will likely have to adapt to what is for them a foreign way of understanding that emphasizes disconnection over connection, impartiality over caring, and objectivity over subjectivity.

The Underrepresentation of Females in the Physical Sciences

Constructing gender as two distinct ways of knowing enhances the understanding of the current issues related to why females avoid college level coursework and careers in the physical sciences. National science education reforms such as *Project 2061: Science for All Americans* (American Association for the Advancement of Science [AAAS], 1989) and the *National Science Standards* (National Research Council [NRC], 1996) address the unequal ratios of females to males who seek careers in science, mathematics, and engineering. These educational reforms state that science ought to be taught in a way that promotes scientific literacy for all. The reforms also suggest that science be taught in a way that is not biased against the experiences of girls or other subgroups. The *National Standards* (1996) recommend that learning outcomes be inclusive to the experiences of the increasingly diverse population of learners in science classrooms. The NRC proposes that science teachers be aware that,

> [I]f an exercise to assess understanding of inertia using a flywheel results in differential performance between females and males, a judgment that the exercise is biased might be

plausible based on the assumption that males and females have different experiences with flywheels. (1996, p. 86)

Females have been and continue to be underrepresented in the physical sciences (Newschatz & Alpert, 1994). Data shows that during the school year 1989-90, the percentage of females in physics steadily decreases from 41% of high school enrollments to 15% of Bachelors degrees to 9% of PhD's to 3% of university faculty (Newschatz & Alpert, 1994). Even though the total number of females attaining college degrees in a broad range of science disciplines surpasses the number of males in the early 1990's, the number of females in physics is significantly lower than males (The National Education Goals Panel, 1994). Female learners are underrepresented in graduate programs in engineering, physics, earth science, chemistry, and mathematics (Matyas, 1985; National Science Foundation [NSF], 1990). Kahle and Meece (1994) suggest that the underrepresentation of females in science is linked to: (1) the large number of males who currently are practicing scientists and teachers of science; (2) the forms of the science curriculum and instruction; and (3) the kinds of classroom interactions which take place in science classrooms. "Regardless of the reason for one's concern," comment Kahle and Meece, "the basic issue remains; girls and later women are underrepresented in scientific and technological courses and careers" (1994, p. 542).

The underrepresentation of females in the physical sciences can be partly explained by the differences in the traditional communicative patterns that distinguish masculine and feminine ways of knowing. In a description of the development of gender identity in modern American society, Gilligan notes that "males tend to have difficulties with relationships while females tend to have problems with individuation" (1982, p. 8). The desired level of relationships and individuation are gender-related phenomena since separation from the mother is fundamental for masculine identification for boys, and connectedness or attachment with the mother is essential for feminine identification for girls (Gilligan, 1982). Harding (1991) adds:

> In order to make female children feminine and womanly, parents encourage a tendency toward concrete and relational thought and a preference for personal, caring service to other people. These traits prepare girls and women to prefer teaching, mothering, and other service and caring activities [in contrast to] those that are essential for careers in mathematics, science, and engineering. (p. 28)

The differences in the desired degree of connectedness between boys and girls contributes to the informal barriers which constrain girls from participating in the physical sciences (Harding, 1991).

The next section reports the methods used in this research. The stories about Sally follow the methods section.

Research Methods

Classroom observation notes, student interviews, student narratives, and classroom documents contributed to the descriptive field text. Observation notes were taken during 52 of 58 one hour and fifty minute class periods. The class met for a total of 12 weeks in a school in the deep south.

Observation notes focused on the student and teacher actions and interactions in the classroom. The teacher and the students were of Caucasian ethnicity. Two girls and eight boys attended the physics class. In total, the researcher observed and participated in 95 hours of classroom instruction. Participation consisted of tutoring students and answering individual questions as students worked independently to solve textbook problems at their desks. The course textbook, course syllabi, student contracts, tests, project rules, science safety rules, and class assignments provided additional sources of data. These items constructed the formal curriculum, assessments, classroom procedures, and rules that outlined the expected student behaviors and learning outcomes.

Sally was the name given to the participating college-bound senior who took part in interviews. Pseudonyms were used in place of real names of persons and places to ensure confidentiality (Soltis, 1989; Tobin, 1992). She shared a student table with another student called Frank. Sally described her classroom experiences through both oral and written text. She attended 18 one-hour audio recorded semi-structured interviews. (She was paid at a rate of $5 per hour for taking part in the interviews.) During the interviews, her prior mathematics and science classroom learning environments were contrasted with the physics classroom. Sally wrote a narrative about her ideal physics learning environment and her willingness to be forthcoming and candid during the interviews. An ethic of care solidified the creation of the stories of Sally (Brickhouse, 1992). For example, she negotiated what would be told in the stories. To maintain rapport with Sally, the interview transcripts were not shared with the physics teacher. After the school term had been completed, the teacher was invited to comment on the stories about Sally, however, no comments have been received.

The field text was categorized into thematic patterns with the aid of the qualitative software program: NUD•IST (*Non-numerical Unstructured Data Indexing Searching and Theorizing*, 1993). Thematic patterns evolved from an examination of the connections among categories in the NUD•IST index tree. Next, thematic patterns formulated storylines. Descriptive stories evolved from the storylines. Sally conducted authenticity and credibility checks throughout the creation of the categories, thematic patterns, storylines, and stories (Guba & Lincoln, 1989).

Stories

Story narratives describe the female student's knowledge in the context of her experienced and preferred classroom learning environments. In this study, "[n]arrative is both a mode of reasoning and a mode of representation" (Richardson, 1990, p. 21). The participating students' behavior, attitudes, and knowledge are represented in the form of student stories. The sense these students make of their classroom experience comes about through a narrative mode of reasoning. Educational researchers have utilized narrative as both a form of storytelling and form of inquiry (Martin & Brouwer, 1993, 1991; Pope & Gilbert, 1983; Clandinin, Davies, Hogan, & Kennard, 1993; Clandinin & Connelly, 1994, 1991; Mattingly, 1991; Ellis, 1994). Clandinin and Connelly suggest that "stories are the closest we can come to experience as we and others tell of our experience" (1994, p. 415).

Coupling narrative as a form of representation and reasoning tells not only what went on in the minds of the students, but it also invites the reader to become an active participant in the research.

Student stories are reviewed and critiqued by the participating students to ensure authentic and credible representations of their experiences. Sally's classroom experiences are storied to describe the learning environment from her point of view. Stories are not only a means of reporting data; stories, as narrative inquiry, promote the understanding of another person's experience through verisimilitude that is the sense or quality of truth. Although a teacher or researcher cannot experience the classroom learning environment directly as a student, a narrative inquiry may enable the reader to experience verisimilitude and thereby connect with the student's experienced and preferred learning environments.

The two stories about Sally focus on the her interactions with the physics teacher, Mr. Benson. The first story *Sarcasm Slows Learning* portrays Sally's experienced learning environment, and the second story *Sally's Ideal Lesson* illustrates her preferred learning environment. These stories follow.

Sarcasm Slows Learning

The assignment did not specifically address physics but could be directed toward any science discipline. The physics students were asked to read a science article, take notes, and present a brief review of the article to the entire class. A week earlier, Sally and the other students had visited the school library to find an article.

Sally volunteered to present her magazine article to the physics class. She spoke about an environmental topic related to water quality. She sat at the edge of her seat while highlighting the major points addressed in the article. The other students were quiet as Sally told the class that logging practices had damaged the salmon streams in the Pacific Northwest. After she finished, Mr. Benson asked her where she had found the article. Upon hearing the title of Sally's magazine, Mr. Benson thrust his arms out from his sides and bellowed: "Sally, you were SUPPOSED to use a magazine from our library for this assignment." His comment caught her unaware. A few students chuckled at Mr. Benson's antics. Sally sat stunned. She could not recall Mr. Benson saying that all the articles had to come from the high school library. Therefore, she had chosen to read a few of the science magazines which her family received at home. Sally thought she had failed.

This was not the first time Sally had not completely understood the parameters of a physics assignment. Quite often, Mr. Benson would list assignments on the chalkboard without clearly explaining the assignment. Many times Sally had only a vague idea about what had been assigned for homework.

After all the students had finished reporting on their articles, Mr. Benson explained that it was important for the students to have used magazines from the high school library so that the librarian would continue to purchase science magazines. If the science magazines were not used regularly then the library subscriptions might be canceled. Sally, one of the more passive students in the class, became upset when she heard Mr. Benson reveal his reasons for having students use the science

magazines from the school library. She believed Mr. Benson had used the physics students to achieve his own ends. Additionally, only two of the nine student presentations that day remotely addressed physics. This assignment did not seem appropriate for a physics class due to the nature of the content as well as to the teacher's underlying motives for using science magazines from the library.

Sally was upset with Mr. Benson's comments about her article. From her point of view, her article was appropriate. Why should she be reprimanded for doing the assignment at home? Should she and the other students be used to further his efforts to convince the librarians of the usefulness of the science magazines? Sally asked Frank, another student, if he could recall anything about limiting the article search to the school library. Frank told her that he couldn't remember Mr. Benson saying anything about it. When the dismissal bell rang, Sally raced out the door.

Sally's anger about the magazine article incident soon subsided and by the next day, she was back to her usual daydreaming in the physics class. Mr. Benson told Sally that her article received full credit. Even though Sally was consoled by the grade, she had lost a bit of respect for Mr. Benson because of the way he had reacted on the day before.

Weeks earlier in another incident, Sally approached the demonstration table as Mr. Benson reviewed papers. She asked him if he had any ideas for her individual physics project. Mr. Benson sniped, "You want ME to tell YOU what topic to choose for YOUR report?" Sally wasn't sure how to respond to his comment. She looked away and replied that she needed some help. Mr. Benson went on to offer a few suggestions after his initial rebuff. This kind of intimidating discourse colored many of Sally's views of the teacher. As the term progressed, she became less willing to talk to Mr. Benson.

The lack of understanding between Mr. Benson and Sally was heightened late in the trimester when she arrived late to class one day. Sally walked up to Mr. Benson who was taking roll at the front podium and handed him an excused tardy pass from the main office. Sally quietly informed him that she was late because the previous day she had received a parking ticket. There had been no room in the school parking lot that morning, so she had parked in a visitor's space to be on time for class. Sally continued that she had just received her driver's license a few weeks earlier and now had a $30 parking fine. She asked Mr. Benson what he thought of her predicament. Mr. Benson looked up from the pass and said that after many years of driving he had never received even a single ticket. Sally let out a terse laugh and replied, "Mr. Benson, how is that supposed to make me feel?" He didn't answer. She returned to her seat and starred out the window.

Another example of the lack of communication between Sally and Mr. Benson took place as students solved textbook problems in class. When Mr. Benson walked by her table, she asked him if her answer to a problem was correct. He replied that it was wrong and moved on. Five minutes later, she asked Mr. Benson if her new answer was correct and again he replied no and moved on without explanation.

A few days later Sally and the rest of the class were again asked to answer textbook problems. Mr. Benson walked by her desk, and Sally asked: "Mr. Benson, is this right?" He may not have heard

her question, because he continued walking across the room. This was the last time Sally would seek his help on homework problems. After this incident, she asked other students for help.

Classroom confrontations between the other students and Mr. Benson had been evident weeks earlier when a few students had been joking and making loud noises in class. On that day, Mr. Benson commented that the entire class had the intelligence of earthworms. Upon hearing this remark, Sally countered quietly that she did not realize earthworms were so smart. This was the only time Sally joked about a sarcastic comment.

Sally did not care for the excessive laughing and horseplay from Chevy, Joe, and others at a nearby table. These students were entertaining at times, yet their joking seemed excessive. Once when Mr. Benson called on Sally to answer a textbook question before the class, Chevy shouted out the answer. Chevy was credited with the answer, and Sally fell silent for the remainder of the period. Sally believed Chevy and Joe, among a few other students, were often out of control in class. She wished Mr. Benson would use his authority to quiet their loud talk and quell their rowdy behavior.

Sally also wondered why she was blamed for not understanding something she had not been taught. Sally wanted to have laboratory activities, demonstrations, lectures, and lecture notes to learn the physics concepts. She wanted Mr. Benson to be more of an active classroom learning leader, rather than simply someone who assigned homework and grades. For her to learn the physics concepts presented in the textbook, Mr. Benson should teach those concepts rather than have the students try to figure them out on their own.

Sally was not learning physics and she placed a fair share of the responsibility on the teacher. Yet at the same time, she acknowledged that she wasn't trying as hard as she could. Rarely did Sally take her physics book home. She never attended Mr. Benson's physics help sessions after school. Sally did not care enough about the class to make that kind of commitment. She went to soccer practice immediately after school, and she wasn't about to skip practice to sit in a classroom with a teacher to whom she couldn't talk.

Sally concluded that physics was only one class out of many which she had taken at Trackview. Even if she did not learn anything significant about mechanics as she had initially hoped, learning was not that important if she could manage a decent grade.

Sally's Ideal Lesson

Sally placed her toothpick bridge aside and laid her head down on her desk. She was tired from staying out late the previous night at the regional soccer tournament. She closed her eyes and soon she was sleeping. During her short nap, Sally dreamed. In this dream, she experienced an alternative physics classroom in which the teacher acted differently. Upon waking Sally realized that in many ways the physics class in the dream was her preferred kind of classroom. The following story is Sally's account of that dream.

I arrived to class just before 8:00 in the morning. As soon as the tardy bell rang, Mr. Benson greeted the class with a hearty "hello" and a cheerful "good morning." It seemed odd to see Mr. Benson

so outgoing and friendly at the beginning of the period. I greeted him and sat at my desk. Mr. Benson explained that we were going to have a laboratory activity and a demonstration. The laboratory dealt with measuring the mass and volume of objects and calculating density. He handed out a paper which listed the laboratory materials and procedures. He asked us to take a few minutes to read it over quietly at our desks.

Mr. Benson divided the students into groups of three. By having Mr. Benson organize the groups, the student bickering about who would go into which group was minimized. Jim and Brian, the smartest students in class, were assigned to different groups. I worked in a group with Alice and Jim. It was ideal to be in a group with Jim because he understood physics and didn't seem to mind explaining things even if it took him away from his own work. It also seemed easy to talk with Alice so I was glad to be with her. Additionally, these two students rarely goofed around in class so it was good to be in their group.

Alice collected the three objects which were to be measured for the laboratory. I gathered the science equipment including a metric ruler, triple beam balance, and a graduated cylinder. After taking the materials to our work station, Jim read the procedures and we began to determine the mass and volume of the three objects. I was not sure which formula to use to determine the volume of the marble, but Jim knew the formula for the volume of a sphere. Alice had a calculator and entered the value for the diameter of the marble and we figured out the volume. It was relatively straightforward to determine the masses of the three objects, but it was more difficult to determine the volume since some calculations were necessary. I knew how to determine the volume of the cube, but none of us were sure how to determine the volume of the bolt. We calculated the densities of the cube and the marble and answered a few follow-up questions from the lab handout.

After the groups had completed the physics laboratory activity, we sat at our desks and watched Mr. Benson conduct the same laboratory we had just finished. Having Mr. Benson repeat the lesson helped to insure that we had a good understanding of the physics concepts related to the laboratory. This was also a good time to ask questions about the laboratory. I asked a number of questions about why our results were not the same as Mr. Benson's for the marble and brass cube. Mr. Benson explained that he used a greater number of significant digits in determining his results since he used a caliper rather than a metric ruler to measure the lengths of the sides of the bolt and the diameter of the marble.

Frank then asked Mr. Benson how to determine the volume of the aluminum bolt. Mr. Benson lectured on how the water displacement method would work for this irregularly shaped object. Mr. Benson demonstrated by filling up a graduated cylinder with water and placing the bolt into the cylinder. He measured the rise of the water column in the cylinder. Since one milliliter of water was equal to one cubic centimeter, it was a straightforward conversion to determine the volume of the bolt by measuring the volume of the displaced water.

The three bolts were the same size but had different masses. Therefore the bolt densities were different. Mr. Benson explained that the iron bolt was more dense than the aluminum bolt and less dense than the brass bolt. After handling and measuring the masses of the three bolts, it made sense

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that the brass bolt was the most dense since it had a greater mass yet the same volume as the iron and the aluminum bolts. In turn, the aluminum bolt was the least dense since it had less mass than the iron and the brass bolts.

The laboratory activity and demonstration lasted for about 50 minutes. Next, Mr. Benson assigned a reading from the textbook which reviewed the physics concepts from the laboratory and demonstration. All the students quietly read from their physics textbook during this 15-minute period. Chevy and Joe began to talk during the reading, but Mr. Benson quieted them by having them sit at separate tables.

After reading the seven-page passage from the textbook, the students and Mr. Benson held discussions about the physics concepts presented in the reading and the laboratory. Then the class moved outside and sat on a grassy patch of the school lawn beneath a large shade tree. The students and Mr. Benson sat with legs folded Indian style. The group formed a circle with everyone facing into the center.

While seated, each student had an opportunity to speak about what they learned from the laboratory activity and the textbook passage. A short wooden stick was passed around the circle. The student who held the stick took a turn and spoke to the entire group while everyone else listened. The teacher could have talked at any time during the discussion; however, Mr. Benson remained quiet while students were speaking. While seated in the circle, each student; (1) received the stick; (2) spoke about what he or she knew related to mass, volume, and density; (3) asked for questions from other students and the teacher; (4) questioned the teacher; and (5) passed the stick to the student seated to their right.

When it was time for questioning, Mr. Benson spoke to the student holding the stick. He talked to each student in a respectful manner which encouraged the student to ask follow-up questions without the fear of being ridiculed or embarrassed. While I held the stick, I spoke about how densities do not depend strictly on mass. Rather density depends on the amount of mass of an object divided by the volume of the object. I did not ask Mr. Benson a question while I held the stick since my questions had already been answered during the demonstration in the classroom.

Upon returning to the classroom, there was a short quiz on the laboratory and demonstration. This quiz was a confidence builder and encouraged me to show what I had learned about mass, volume, and density. Since the quiz was not too difficult, I did fairly well on it. After three or four classroom activities a test would be given highlighting the concepts presented in the previous laboratories, demonstrations, and discussions.

At this point in her dream Sally awoke and sat up in her chair. She rubbed her eyes and looked toward the clock. Surprisingly, only a few minutes had passed since she had lain her head down. Frank was gluing a toothpick to his bridge at the other side of the table. Sally picked up a toothpick and touched a glob of glue to it and pressed it against a truss on her bridge.

Interpretations

Care

From the first story, *Sarcasm Slows Learning*, the physics teacher's classroom humor interferes with Sally's attempts to learn physics. She interprets the teacher's humor as sarcastic and hurtful at times. Sally interprets his language as a form of male aggression. In her view, Mr. Benson's vocal tone and body posturing is demeaning. This kind of language not only shows that he doesn't care about her or her learning, but it also diminishes her desire to answer homework problems, to attend tutoring sessions after school, and to study for physics tests. Sally becomes less motivated to read the physics textbook or attempt the assigned mechanics problems. To become more motivated to learn physics, she needs to communicate with the teacher in a style that is familiar to her.

Sally assumes a passive role in her classroom and minimizes her responses with the teacher. Her silence in the physics class relates to the teacher's failure to be an empathetic listener (Gilligan, 1989; Belenky et al., 1986). Noddings refers to empathetic listening as engrossment (1992). Accordingly, "engrossment does not mean infatuation, enchantment, or obsession but a full receptivity" (Noddings, 1992, p. 16). In Sally's opinion, the teacher is not a receptive listener. When she does speak with him, he often uses a kind of humor which embarrasses her. When Sally asks for help on an assignment dealing with Newton's Second Law of Motion, Mr. Benson seems too busy to take the time to help her understand the assigned mechanics problems. Evidence of Mr. Benson's preoccupation is: (1) he does not ask Sally follow-up questions; (2) he is rushed in both his speech and his movements about the room; (3) he reminds the students that he is busy with the school science fair; and (4) he frequently answers telephone calls in his office and speaks with classroom visitors during the class period.

Sally fails to communicate effectively with Mr. Benson due to their incompatible perceptions of the kind of dialogue appropriate for the physics classroom. Sally believes it is important to communicate with the teacher with an empathy and care. Yet she finds it difficult not only to talk with Mr. Benson, but also to communicate with other male mathematics teachers at Trackview. According to Sally, female teachers are more receptive listeners than male teachers. Female teachers are less likely to use technical jargon, but if they use technical terms, they explain the terms. Sally believes that it is easier for her to talk with female teachers since they look directly at her when she speaks and their facial expressions show that they care about her and what she has to say. From her experience, female teachers care more about students and student learning. This form of caring for the student, motivates Sally to take more interest in learning the subject content. Learning the subject content becomes more important than earning a good grade when Sally believes the teacher genuinely cares about her and her learning.

Another interpretation of Sally's passivity in the classroom results, in part, from her perception that the teacher's tone is aggressive. Gilligan states that, "[s]ex differences in aggression

are usually interpreted by taking the male response as the norm, so that the absence of aggression in women is identified as the problem to be explained" (1982, p. 43). Rather than consider Sally's classroom reticence as a sign of her lack of motivation to learn physics, the teacher's aggressive posturing ought to be considered the primary cause for Sally's disengagement and subsequent lack of learning. This perspective evolves out of Sally's belief that the teacher's sarcastic humor does not foster care.

Connectedness

A connectedness exists between Mr. Benson and Sally in *An Ideal Lesson.* In this story, the teacher is friendly, encouraging, and receptive to the students. Mr. Benson structures activities that promote student dialogue and participation. In Sally's eyes, the circle-talk is not considered a leveling of the power relationships among the students and the teacher. Rather, the circle-talk is an opportunity to engage in what Tannen (1990) calls "rapport-talk" which emphasizes connectedness between the speaker and the listeners. Rapport-talk is a way to make the classroom less formal and invite more intimate forms of communication. According to Tannen:

> People feel their closest connections at home, or in settings where they *feel* at home--with one or a few people they feel close to and comfortable with--in other words, during private speaking. But even the most public situations [like classrooms] can be approached like private speaking. (1990, p. 77, italics in original text)

Sally wishes to engage in rapport-talk in the classroom because she communicates most effectively in less formal settings. The circle-talk enhances her voice since she can communicate in a caring, connected way.

Based on Tannen's (1990) research, report-talk is formal public discourse where a speaker imparts information to those who are less knowledgeable. Males frequently engage in report-talk, yet Sally report-talks as she describes her science journal article to the class. In the physics classroom setting, Sally permits the more competitive male students to respond to her question because she is not comfortable with report-talk. Many female students do not wish to engage in report-talk for the following reasons: (1) they do not wish to appear smarter than the boys in the classroom; (2) they do not feel it is important to gain status in the public setting by displaying their knowledge to the other students; (3) they do not feel confident in their abilities to understand science; and (4) they believe that public speaking is a form of showing off which is in opposition to their desired goal of building intimate relationships to foster the classroom community.

A connectedness exists between Mr. Benson and Sally in *An Ideal Lesson.* This story illustrates Sally's preferred physics classroom environment. In this setting, she is able to learn mechanics through a personal connectedness with the teacher. A vital component of this connectedness is her ability to communicate openly with him and other students in the classroom. Kahle (1985) notes that girls prefer to have science learning environments where they can ask questions and take part in classroom discussions. In Sally's ideal science classroom, interactions are modeled after the circle-

talk where each person's voice is valued. The circle-talk is an informal instructional method designed to create a learning atmosphere that facilitates question and answer conversations which enhance student learning.

The teacher's pedagogy also relates to the quality of interactions in the physics classroom. In Sally's ideal lesson, the teacher engages the students in a variety of hands-on activities which enhances their understanding of physics though greater involvement and interactions with both the teacher and other students. Kahle (1985) notes that laboratory instruction effectively increases a female learner's interest in science. Sally desires to learn physics by conducting hands-on activities in the classroom laboratory. In contrast, Sally's experienced learning environment, the large quantity of individual problem-solving limits her interactions with others and her subsequent understanding of the physics concepts.

Sally's preference for the circle-talk activity illustrates her belief that learning occurs in nurturing environments that foster empathy and cooperation. Sally and the other students do not argue to contradict the ideas of others. Rather, Sally--and the others in the circle-talk--are supportive listeners who try to understand each other's ideas to make better sense of their own. Sally prefers not to debate or compete with other students during the circle-talk to prove her point. Instead, she is willing to mold her schema according to her interpretations of the compatibility of the ideas of others.

Sally and many of the male students in the classroom do not play by the same rules during classroom discussions. Many female students do not attempt to gain status in their interactions whereas many of the males constantly employ status seeking behaviors. The male students in the classroom act out to signify their independence and the separateness from the teacher and from one another. They gain status by violating the teacher's classroom rules. However, Sally is not seeking status in the classroom. Rather she is seeking connectedness in the classroom community.

Sally can not understanding why the boys behave as they do in the classroom. She attributes their rule breaking behavior from an essentialist perspective, i.e. that is how boys are. She believes that men teachers and some male students talk with a technical language to show that they are knowledge experts. Sally becomes nervous when she observes the males in the classroom insulting one another. Although the males in the classroom may consider their bantering a form of playful posturing, Sally believes their actions splinter the classroom community.

Mr. Benson's forms of instruction also relates to the quality of interactions in the physics classroom. During Sally's ideal lesson, the teacher engages the students in a variety of hands-on activities which enhance her understanding of physics. Sally becomes more involved with the teacher and other students as she learns about density by reading the textbook, observing the demonstration, conducting a laboratory, and engaging in classroom discussions with her peers.

One of Sally's expressed classroom goals in the classroom is to get along with other students and the teacher even if she does not really care for them. In a study of preadolescent girls in educational contexts, Brown and Gilligan (1992) note that many girls struggle between openly sharing their honest views and attitudes for others and maintaining a perception of the "perfectly nice and caring

girl" (p. 39). This comes about through girls' struggles to minimize personal conflict (Tannen, 1990). In relation to Mr. Benson, Sally would rather acquiesce to what she perceives as his sarcastic attitude rather than confront him and heighten personal conflict.

Sally's efforts to get along with others in the classroom result in her being a connected knower. In the classroom, Sally often talks with Alice about topics unrelated to physics. She feels most comfortable speaking with Alice since they can talk about issues important to them. Sally refers to these issues as "girl concerns" such as hair styles and jewelry. However, it is not just the topic of conversation which makes it easier for Sally to speak with Alice--the only other female in the class. It is easier for Sally to personally connect to Alice's experiences since Alice is a girl. According to Sally, boys and girls have a different way of communicating and understanding. Sally's belief is consistent with Tannen's (1990) view that girls share similar ways of communicating and interpreting experience. Sally's desire to communicate with Alice does not mean that they are friends. Even though Sally and Alice have attended Trackview High School together for a number of years and have had many classes together, Sally chooses not to spend her out-of-school time with her. It is a combination of their personal responsibility to develop a sense of community which bring these two female students together in the physics classroom (Tannen, 1990).

Voice

The loss of the feminine voice in the physics class is not so much an issue of not hearing the words spoken by the female students, it is a failure to listen to their language through a connectedness and caring (Gilligan, 1989; Belenky et al., 1986; Noddings, 1993). Sally strives for connectedness and caring in the classroom with a male instructor who uses language which is considered intimidating and offensive. Sally believes that the teacher's sarcasm is a poor model for fostering female voices.

Sally is soft spoken and often silent in the physics class. When she explains her science article before the class in *Sarcasm Slows Learning*, she speaks with an hesitant voice--similar to the way that Alice talks before the class. Sally is reluctant to engage in public speaking or what Tannen (1990) calls 'report-talk.' Regarding the dynamics of public speaking and gender, Gilligan (1989) writes:

> The difficulty women experience in finding or speaking publicly in their own voices emerges repeatedly in the form of qualification and self-doubt, but also in intimations of a divided judgment, a public assessment and private assessment which are fundamentally at odds. (p. 16)

This doubt comes about through experiences in which girls come to "question the normality of their feelings and to alter their judgments in deference to the opinions of others" (Gilligan, 1989, p. 1993). In Sally's mind, girls are supposed to be feminine which means that they should not offend people. Girls should cover up their own voice in many public settings and submit to the views and ideas of others unless they feel very strongly committed to something. For instance, when Sally is questioned by Mr. Benson about her science article, Sally begins to respond but is interrupted by Chevy who answers her question. Although Sally read the article and knows what it contained, she allows Chevy to answer her

question. Sally does not have a conviction to speak up on this issue. Her belief that she ought to be quiet and passive limits the development of her voice in the classroom.

In a follow-up interview with Sally, she states that if she felt committed about the article issue, then she would have spoken out. Sally's reluctance to compete with the male voices has been enculturated within her as normal behavior for girls. Sally is a female learner, like many other female learners, who would rather silence her own voice than compete with the voices of others and create discord within the classroom community. Sally's decision not to speak out reinforces the stereotype that boys rather than girls are more vocal, more willing to take risks, and more likely to succeed in science.

Gender and the Learning of Science

Sally discredits her own ability to learn mechanics. She does not want Mr. Benson to reveal her test scores to the other students. She reasons that other students will think of her as "a dumb girl" if they discover her test scores (interview transcript, 1/95). Sally's metaphor for linking the feminine gender with the debasing and anti-intellectual adjective 'dumb' hints at her underlying beliefs regarding the role of females in the physics class. Her interpretation is consistent with Kahle's (1985) observation that many female learners tend to underestimate their abilities in science. In reflecting on her ability in the physics class, Sally acknowledges that she is not a dumb girl, but she fears that other students will think of her that way. Being thought of as a dumb girl is not so much a loss of status for Sally; in her eyes it invites the potential for losing connection with other students in the class. She believes that other students will not want to jointly solve problems with her if they consider that she is dumb.

In discussing the male students who score poorly on tests, Sally does not use the term "dumb boy" to describe them. Instead, she says that these students just don't care enough about the class or their grade so they don't try hard enough. Sally believes that males have the ability to learn science if they try. This differentiation in the abilities of males and females exemplifies Sally's lack of confidence in her own ability, and perpetuates the myth that boys are better adapted to pursue studies in the physical sciences.

Sally believes that some girls, like Alice, can apply themselves to be successful in physics, but they need to try work harder to make the transition from being what Belenky et al. (1986) call connected knowers to procedural knowers. Working with the ideas of Gilligan (1982) and Noddings (1984), Belenky et al. propose that connected knowing not only involves situating the self in connection with others but it also means connected the self with ideas and things. Separate knowers think critically and they adopt an objectivist stance which separates the knower from what is known.

It is difficult for female learners like Sally to project their voices in physics classrooms since their classroom experiences are often foreign to their familiar form of conversation. Sally has not made the transition from a connected form of knowing to a separate form of knowing which is useful in the lecture/textbook form of instruction which predominates in the physics class. The transition from

connected to separate forms of knowing is more developed in the life experiences of boys (Gilligan, 1982).

Frank and the other male students in the class take part in a many more interactions with the teacher in the physics class as compared to the Sally and Alice. The boys are more willing to take risks because they wish to gain status and receive recognition by having the right answers, by challenging the teacher's authority, and by gaining attention by joking in class. The adolescent boys cooperate with the teacher to the degree that asking and answering questions and being recognized before the entire class enables them to gain status. These differences in how boys and girls interact in science classes has an effect of lowering expectations for many female learners. Kahle and Meece agree:

> Compared with girls, boys are more likely to initiate teacher interactions, to volunteer to answer teacher questions, to call out answers, and to receive praise, criticism, or feedback to prolong teacher interactions. These classroom interaction patterns result in greater opportunities for boys than girls to learn in science and may reflect favorable achievement expectations for boys. (1994, p. 550)

Science teachers, both male and female, who believe that male assertiveness is an indicator of interest and ability in science will more likely expect more from their male students. Thus, being passive acts to disadvantage girls in many science classrooms.

Implications

Science educators need to reflect critically on their own classroom language to enhance the participation and subsequent learning of girls. The following issues urge science educators to critically reflect on their instructional strategies and interactions with female learners in classrooms. These comments are not intended to be generalized to the whole population of female learners. Rather, they represent what was learned from the authentic representation of Sally's experienced and preferred physics classrooms. Her experiences are consistent with those of many females enrolled in high school physics classes, but not all.

1 Female learners, like Sally, desire a high level of connectedness with their teachers to learn the science content. These learners want to enter into caring relationships to develop rapport with the teacher. For teachers to develop rapport with female learners, they ought to co-construct caring classroom environments which all learners perceive as warm and friendly. Classroom discussions ought to enable learners to engage in rapport-talk, like the circle-talk example, to enhance the development of voice for girls. Female learners need to develop rapport with their teachers to make sense of their experiences through a form of caring and connectedness with both the subject content and the others in the classroom.

2 The teacher's use of classroom humor may constrain connectedness and repress the voices of girls if they believe that the teacher's humor is sarcastic. From the perspective of female learners,

sarcasm is a form of aggression that breaks the bonds of connectedness between the teacher and themselves or any other person. Aggressive language employed by many males is a form of status posturing that can undermine the learning climate for many female students. Classroom humor may be used by males as a vehicle to gain status in the classroom, but girls consider this kind of communication as a personal attack, even if that is not intended by the teacher. Male teachers may use humor in an attempt to develop rapport with students, only to have it backfire and create animosity in the classroom. Tannen explains that, "women are inclined to misinterpret and be puzzled by the adversativeness of many men's ways of speaking and miss the ritual nature of friendly aggression" (1990, p. 150). As a result of this kind of dialogue many female learners turn inward and minimize their interactions with the teacher. In Sally's case, the teacher's humor shuts down her openness to the teacher and her willingness to learn physics. Female students enjoy laughter and have a sense of humor, however, they do not like to laugh out of a feeling of embarrassment.

3 Question and answer activities in the form of the circle-talk facilitate classroom dialogue in an environment where female learners develop voice. These kinds of classroom activities are opportunities for meaningful classroom conversations premised on connectedness and caring. Sally's circle-talk takes place on the school lawn beneath a tree because this kind of outdoor environment models the circle-talk that she was familiar with during a summer camp experience. Sally prefers to sit on the ground in an unconventional classroom setting--on the school lawn. Although this may not be practical in many classroom settings, it is possible to set up discussion activities by reconfiguration the classroom furniture into circular shapes, or science teachers may utilize school resource rooms to offer novel settings.

4 Multiple science instruction strategies such as laboratory activities, demonstrations, and discussions enable female students to enter into caring relationships which facilitate their understanding of physics. Female learners want to learn from a variety of instructional methods to become involved in content oriented conversations with students (lab partners) and their teacher. Multiple forms of instruction may motivate female learners to become more active in the classroom to learn physics.

Conclusions

Sally is a female student who learns through caring relationships and connecting the subject content to her own personal experience. In Sally's experienced physics classroom, she is taciturn since she cannot engage in a caring and connected relationship with him. In Sally's preferred physics classroom, however, she is able to engage in effective communication since she and the teacher develop rapport. She is also able to take part in many kinds of learning activities to learn the physics concepts. These activities call for different kinds of communication with other students as they jointly solve problems and discuss what the concepts mean.

From Sally's perspective, knowledge is constructed through an empathetic understanding among individuals. She advocates the circle-talk session to learn physics rapport-talk. Sally wanted to engage in a caring relationship with the teacher; however, she does not because of the teacher's use of technical language and his perceived apathy for her. The teacher's sarcastic humor acts to constrain Sally's relationship with him. As a female learner, it is problematic for Sally to make the transition between her familiar way of connected knowing and the objective or technical way which seemed to be valued by the teacher and the textbook.

With the current lack of female participation in the physical sciences, it is imperative that science teachers consider ways to encourage girls to learn science. For this to happen, science teachers need to engage in rapport-talk, teach in ways that value the voices of girls, and limit male status seeking posturing which silences the voices of girls. Sally's voice is valued when she is able to capitalize on her familiar way of knowing in the classroom. As the classroom becomes less formal she is able to engage in more intimate conversations to learn the physics concepts. This implies that science teachers who include activities which strengthen rapport with female students may develop more inclusive learning environments.

Male science teachers may promote learning for all if they are cognizant of feminine ways of knowing emphasizing caring and connectedness. Structuring science teaching in a way that is sensitive to both feminine and masculine ways of knowing is consistent with the recent calls for reforming science education. If feminine ways of knowing are not considered in the planning and delivery of science instruction, females may continue to be silenced in classrooms and underrepresented in the physical sciences.

Apart from the underrepresentation of females in physics, mathematics, and engineering, the goal of including feminine ways of knowing holds the potential to recasts science in a post objectivist paradigm. To move beyond science as a value-free, objective inquiry into an universe separate from the self, scientists and science educators ought to assess alternative ways of knowing that are consistent with the worldviews of many females.

Finally, physics education should be re-examined to expose the masculine hegemony that has disenfranchised many female learners. To make science an inclusive endeavor, science educators ought to reflect on their beliefs regarding how males and females learn science. Girls should not be discouraged from studying physics simply because they have an alternative way of knowing. Rather, physics teachers should motivate female learners to learn physics by planning and conducting instruction that values both masculine and feminine ways of knowing. Secondary physics classrooms can become rich learning communities where the voices of girls flourish if teachers allow girls to learn the subject matter in a caring and connected way.

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